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Introduction

Major changes in weed management during the last 5 years have resulted in a number of new considerations and emerging issues for the Midwest. Notably, the change in herbicidal weed control that emphasized the acetolactate synthase (ALS) inhibitor herbicides to weed control based primarily on genetically modified (GM) crops and glyphosate resulted in a number of considerations. These issues focus on the cost of weed control, the simplicity of glyphosate-based systems, changes in weed populations, herbicide resistance in weed populations, and the implications of highly focused selection pressures on agroecosystems.

While GM crops, particularly soybean, predominate the Midwest with an estimated 80% of the acres planted, herbicides other than glyphosate continue to be used, albeit at a lesser frequency than in the past. Many of these herbicides have soil residual properties and given the current dry conditions in Iowa, there is some potential for herbicide carryover to crops in 2004.

This paper will address a number of these issues and attempt to provide the reader with an indication of the relevance and importance of each topic. Several of the topics considered will only raise questions without providing any conclusions thus resolving the issue. Also, some of the topics are more of academic, rather than commercial agricultural interest. However the author feels strongly that practitioners should be aware of these issues in order to consider the benefits and risks of adopting a particular strategy or system by which to manage weeds.

Implications of GM-based weed management systems

The adoption of GM soybeans is unprecedented in modern agriculture. The concomitant adoption of glyphosate as the primary, if not sole herbicide used for weed control was even more pervasive than the change to ALS herbicides in the mid-1980s. While the adoption of glyphosate resistant corn hybrids has not been as complete as was experienced in soybeans, the percentage of acres planted to glyphosate resistant corn is significant. Importantly, this will result in a significant number of growers in Iowa using glyphosate based weed control in both corn and soybean. Given that multiple applications of glyphosate are typically required to meet weed control expectations, the selection pressure brought to bear on the agroecosystem may be as severe as the selection pressure attributable to weed control systems based on ALS inhibitor herbicides, despite the lack of soil residual afforded by glyphosate. Thus, the author suggests that problems similar to those experienced with the ALS inhibitor herbicides are possible for the future.

Cost of weed management

One of the primary features growers favor for the GM crops and glyphosate-based weed control is the reported lower cost of weed control. Glyphosate-based weed control has significantly eroded the value of other herbicides to the point that there is little profit incentive for companies to develop new products. This represents a potentially serious problem for future weed management. From the growers' perspective, however, the precipitous drop in price of residual herbicides represents an important opportunity.

It is important to consider all costs attributable to the GM crops. Notably, the technology fees are reported to increase in the future. The technology fee should be ascribed to weed management costs. Furthermore, while glyphosate cost is currently at an unprecedented low, the cost of multiple applications significantly elevates the overall cost of weed management. Growers also need to recognize that poor application timing or failure to use the appropriate amount of glyphosate also has inherent costs due to loss of potential crop yield.

The author suggests that due to these costs, the inclusion of a residual herbicide prior to, or immediately following, planting has a significant economic benefit for the grower. Recognize that a residual herbicide does not need to provide "season long" weed control to have merit in a weed management program. Reduced rates of residual herbicides may provide sufficient weed control to allow one postemergence application of glyphosate to control weeds well enough to meet grower and landowner expectations. More importantly, the use of a residual herbicide minimizes many risks that accompany a glyphosate-based weed control program.

Risks attributable to simplistic weed control systems

There are a number of risks associated with current weed control systems, and most of these risks reflect the benefits of a simple system based on one herbicide that can be applied without concern for herbicide injury to the crop, applied over a long period of crop development, and provides relative consistent control of most weeds that exist within the weed communities. Growers assume that because weed control programs based on glyphosate are "simple" due to the fact that only glyphosate is used in many instances, there are no management considerations.

In fact, weed control programs that are based on postemergence herbicide applications, regardless of product(s) used, are extremely complex and require considerable management skill. These systems require an understanding of weed biology, the interactions of the weed community and the crop, and a feeling about how the environmental conditions affect the system.

Perhaps the greatest misconception demonstrated by growers is the reason that herbicides, or better said, weed management tactics, are universally employed in crop production systems. Growers assume that weed management tactics are employed to kill weeds. However, in reality, the reason growers use herbicides is more correctly stated to protect crop yields. This seemingly simple yet subtle difference in why herbicides are used has significant implications. Failure to fully appreciate this difference is demonstrated consistently in Iowa soybean production systems based on Roundup Ready ® technology where yields are often lower than growers' expectations; weeds control is acceptable and yet the yield is not. The yield reduction is not attributable to the genetic basis of the glyphosate resistance but rather the failure of growers to appreciate the interaction between weed communities and soybeans. The weed community was allowed to interact with the crop too long resulting in interference and irretrievable yield loss regardless of how many weeds were killed.

Thus, in essence, weed management tactics based on postemergence herbicides, while seemingly simple, particularly those based on GM technologies, there are many complexities and subtlies that must be accommodated. Most importantly, the period of time when weed communities and crops can "safely" interact without a risk of yield loss cannot be consistently predicted. Thus, alternative weed management strategies like the inclusion of a soil-applied residual herbicide prior to, or immediately following planting, is an excellent risk management tactic.

Other risks associated with simplistic weed management systems include concerns for herbicide drift, the movement of GM traits through pollen, weed population shifts, and the evolution of herbicide resistant weed populations. These topics are detailed below.

Off-target movement – herbicide and pollen

Herbicide drift is a significant issue for agriculture regardless of the technologies that are included in the crop production system. However, with the use of multiple applications of postemergence herbicides, particularly herbicides that can be applied over a long period of time during the growing season, and herbicides that have limited selectivity, the implications of herbicide drift are suggested to be greater than for "conventional" weed management programs. Growers and custom applicators have been relatively successful in managing herbicide drift. However, it is suggested that as farm size continues to increase, and the adoption of weed management systems that rely on non-selective, non-residual herbicides becomes universal, there will be a greater tendency to apply herbicides during conditions that favor off-target movement. Thus, herbicide drift represents an important risk to simplistic weed management control systems.

The other issue, off-target movement of pollen, is suggested to be a future concern in Iowa corn production. The risk is reflected in the movement of genetic traits from one field to another. Research has demonstrated that the frequency of trait introgression is reduced as the distance away from the pollen source is increased. However, achieving a zero tolerance level as some growers and environmentalists demand is not possible in the current agricultural production systems. Importantly, this is not a new risk attributable to the adoption of GM-based crop production systems. In reality, pollen movement and subsequent trait introgression has occurred consistently in Iowa each growing season. However, the herbicide resistance trait associated with the new technologies is easily identified and thus there are newfound concerns.

The risk of pollen movement from a GM field to a non-GM field represents a significant economic problem for some growers who have contracts to grow non-GM corn. It is anticipated that the risk associated with off-target pollen movement and resultant attention will escalate in the near future and become a serious problem for simplistic weed control systems.

Weed population shifts

Weed population shifts occur in response to changes in the agroecosystem. These changes reflect in selection pressure(s) that alter the relative competitive abilities of weed populations that comprise the weed community for a given agroecosystem. When crop production systems change, whether the change(s) reflects different tillage, crop rotations, fertility programs, or weed management programs, the selection pressure(s) that favor specific weed populations within the weed community is altered and weed populations that were at one time less competitive become more competitive and thus more prominent in the weed community. It is important to recognize that a weed population shift may occur with a weed population in the existing weed community, or with a weed population that is introduced into an existing weed community. An example of a weed shift for a weed population previously existing within the weed community is the rise in prominence of common waterhemp (Amaranthus tuberculatus). An example of an introduced weed shift is the increase of woolly cupgrass (Eriochloa villosa) populations across Iowa.

There are a number of reasons weed population shifts have occurred in Iowa. Notably, the adoption of conservation tillage practices has, in part, accounted for the increase in common waterhemp populations. Another critical factor affecting changes in weed populations is herbicide use, both specific product and application timing. The reduced use of atrazine and Treflan, the prevalence of Bladex use in southern Iowa during the 1970's and 1980's, and the use ALS inhibitor herbicides in the late 1980's contributed significantly to the rise in prominence of common waterhemp in Iowa.

Typically, no one single factor or condition will cause a weed population shift. In fact, the reasons weed population shifts occur are likely attributable to the interactions of factors and conditions and are likely very complex from a biological and genetics perspective. The main consideration is that a specific weed population becomes more ecologically adapted to an agroecosystem due to changes in crop production tactics. The improved ecological adaptation results in the weed population being more competitive than other weed populations and thus the most competitive weed population displaces the other(s).

New weed populations that appear to be increasing in local prominence include wild buckwheat (Polygonum convolvulus) in Northeast Iowa, Asiatic dayflower (Commelina communis) in East Central and South Central Iowa, giant ragweed (Ambrosia trifida) in Eastern Iowa, and winter annuals across the entire state. A weed that has the potential to become a greater problem is Palmer Amaranth (Amaranthus palmeri) in Southern Iowa. Again, whether or not these weed populations become significant economic problems depends on a number of complex interactions. However, in many instances, the factors that will most influence weed population shifts are tillage and herbicides. It is important to note that the weeds mentioned above appear to be adapted to conservation tillage systems and several demonstrate tolerance to glyphosate.

Update on herbicide resistant weed populations

Herbicide resistant weed populations continue to be an issue in Iowa, however generally speaking, they do not appear to be of economic importance given the changes in herbicide use patterns (i.e. the adoption of glyphosate programs). Despite this, populations of ALS resistant giant ragweed, common sunflower (Helianthus annuus), and shattercane (Sorghum bicolor) have recently been confirmed in Iowa. Furthermore, ALS resistance in common waterhemp populations is extremely common and may represent the norm rather than the exception.

While Iowa State University Weed Science has conducted considerable research on glyphosate-resistant horseweed (Conyza Canadensis), no populations in Iowa have been identified. However, glyphosate-resistant horseweed populations have been identified in Missouri and Illinois. Experiences from the Eastern Corn Belt suggest that if horseweed populations become more prominent (i.e. a weed population shift), it is probable that glyphosate use will select for glyphosate resistant biotypes. Given that horseweed is a prolific seed producer and that the seed is wind-disseminated, the spread of glyphosate-resistant populations could be very rapid, as experienced in the Eastern Corn Belt.

Iowa State University Weed Science has also conducted extensive research on glyphosate resistance in common waterhemp. The existence of glyphosate resistance in a very low percentage of plants in fields has been confirmed. However the frequency of the resistant plants is extremely low. Given that common waterhemp is dioecious and the resistance to glyphosate appears to be controlled by several genes, it is unlikely that glyphosate resistant common waterhemp populations will become of economic significance in the near future.

There has been some discussion about the evolution of common lambsquarters (Chenopodium album) populations that are resistant to glyphosate. Numerous calls from growers during Summer 2003 indicated problems controlling this weed with glyphosate. Observations suggest that the control problems were most likely attributable to management problems rather than the evolution of resistance. However, research programs in Minnesota and Wisconsin have been initiated to investigate whether or not management or resistance is the problem.

Herbicide carryover

Given the dry summer, particularly in Southwestern and Western Iowa, there is some risk for herbicide carryover. Given that ALS inhibitor herbicides cloransulam-methyl (Gauntlet and FirstRate), imazethapyr (Pursuit), imazaquin (Scepter) and chlorimuron-ethyl (Canopy and Classic) have excellent soil residual characteristics, local conditions experienced in 2003 may result in some potential for carryover to corn in 2004.

The relative risk of carryover depends on the rate of the herbicide applied, the application date, soil characteristics and moisture conditions. Also important are the growing conditions next spring. If conditions place the seedling corn under immediate stress, herbicide carryover symptoms are likely to be more severe due to a reduced ability of the corn seedling to metabolize the herbicide. Furthermore, if an ALS inhibitor herbicide is applied to the corn, an interaction between the carryover ALS inhibitor herbicide and the current herbicide is likely and will result in greater injury than either herbicide would cause alone.

Fomesafen (Flexstar) has also demonstrated some potential to cause carryover injury to corn. Again, the same general environmental considerations and corn health will determine the relative severity of the potential carryover injury.

Isoxaflutole (Balance Pro and Balance) and mesotrione (Callisto and Lumax) have some potential for carryover injury to soybeans in 2004. Several fields in Indiana demonstrated isoxaflutole carryover in 2003. In Wisconsin, two soybean fields demonstrated mesotrione carryover. Factors that were consistent with the isoxaflutole carryover occurrences were low soil pH (<5.5) and low soil organic matter (<2%). Symptoms included some chlorosis, stunting, and a strapping of leaves. It is not anticipated that isoxaflutole or mesotrione carryover will be a big problem in Iowa.

General weed management recommendations for the future

The best recommendations for future weed management programs would be to use as many alternative tactics to manage weeds as possible. Recognize that while simple weed control programs are desirable, simplicity has associated risks. Determine if solutions to resolve weed control problems exist if your desired simplistic program fails. Also, what is the cost of these solutions, if any solutions are available? What is the risk of not being able to apply the first (and most important) herbicide application in a timely fashion? Remember, the goal of a weed management program is to protect crop yield potential, not only to kill weeds.

Avoid risks if possible, and if some risks must be accepted, determine the cost of those risks. However, it is difficult if not impossible to accurately assess some risks. For example, while the evolution of herbicide resistant weed populations is inevitable if the selection pressure brought to bear upon the weed populations is consistent and effective, in many cases, it is difficult if not impossible to predict when the problem will develop. Furthermore, it is impossible to assess what new technologies may become available in the future. These new technologies may resolve the problem. However, given the current situation in agriculture, it would be inappropriate to presume new solutions to future problems will be developed. Thus, the best strategy to assess the cost of future herbicide resistant weed population would be to estimate the cost of resolving the problem using currently available herbicides and tactics. Recognize that diversity of weed control tactics has long-term merit and that simplicity has economic and ecological risks.